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PARTIAL COMPLIANCE TESTING OF AUTOMOTIVE INFANT RESTRAINT SYSTEMS TO CANADIAN MOTOR VEHICLE SAFETY STANDARD 213.1

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Table of Contents

	Page
List of Figures	iii
List of Tables	v
Summary	vii
1. Introduction	1
2. Test Equipment and Instrumentation	1
3. Data Recording and Processing	3
4. Test Requirements and Methodology	4
5. Compliance Test Results	8
6. Conclusions	9
References	10

Attached Appendices:

A. Buckle and Dynamic Test Requirements from CMVSS 213.1 "Infant Seating and Restraint Systems"	21
B. Determination of the Carrier Back-Support Angle	23
C. Sled Acceleration Plots	27
D. Amendments Proposed for CMVSS 213.1 and MVSTM 213.1.	53

Auxillary Appendices

E. Edited 16-mm high-speed movie film of all runs, from two cameras

F. Two Polaroid Graph-Check prints taken during the impact for each run

G. Slides (35-mm) of pre- and post-test carrier set-ups for each run

H. Three Polaroid prints of each carrier taken during the measurement of the back-support angle

List of Figures

		Page
1.	Specification for Test Platform Acceleration, as per MVSTM 213.1	11
2.	Standard Bench Seat on Sled, with Carrier and Infant Dummy	12
3.	Six-Month-Old Infant Dummy	13
4.	View of Seat Bench From the Right Lateral Movie Camera ...	14
5.	View of Seat Bench From the Left Lateral Movie Camera	15

List of Tables

		Page
1.	Compliance Test Conditions and Results	17
2.	Carrier Data	19

Summary

The test procedures and results of a series of impacts using the Impact Study Facility's HyGe crash simulator are presented. This work was conducted as the first phase of a two-part contract with Transport Canada, where the objective was to determine the compliance of all commercially-available automobile infant carriers in Canada according to the regulations for buckle and dynamic testing in the Canadian Motor Vehicle Safety Standard (CMVSS) 213.1, "Infant Seating and Restraint Systems". The pertinent regulations in this standard are explained, and the test procedures which were adopted for each are given. Except where noted, the simulated impacts were carried out in strict accordance with the regulations in this standard. The results, which are presented in full, demonstrated that all but 2 of the 11 infant seats met all of the regulations in CMVSS 213.1; those two carriers each failed one regulation. Numerous changes to the regulations and the laboratory test procedures, which were requested by Transport Canada, are given in detail, along with recommendations proposed by DCIEM for amendments to the Standard.

1. Introduction

The use of infant carriers in passenger cars has increased dramatically in the past ten years in North America, largely as a result of the increased public awareness of automobile safety devices such as seat-belt restraint systems. Such systems were found to effectively reduce fatalities and injuries in vehicular impacts; consequently, Federal and Provincial statutes were passed which encourage, and often require, the use of seat-belt restraint systems in most Canadian provinces.

However, when adult restraint systems were introduced, it was recognized that children could not be adequately restrained by the standard adult restraint systems, and that their protection would require a special and separate carrier. From 1972 to 1982, the sale and importation of child carriers in Canada were regulated by the Hazardous Products Act (1). These regulations governed carriers for children weighing up to 34 and 48 pounds, representing 50th-percentile male, white, three and six-year olds, respectively. In general, since the development of infant carriers followed that of child carriers, they were not specifically covered in the Act; and, therefore, there was no lower limit on either age or weight. (Infant carriers were later defined as carriers for children from birth to approximately six months of age, and weighing from 7 to 17 pounds.) This omission was rectified on September 1, 1982, when new Federal regulations, which set standards for infant carriers (2), came into effect. These regulations are known as the Canadian Motor Vehicle Safety Standards (CMVSS), Section 213.1, "Infant Seating and Restraint Systems". Further regulations were drawn up, effective March 1983, which govern the sale of booster cushions. These are intended to raise children up to 6 years of age several inches higher on an automobile seat, in order to allow an adult lap and shoulder seat-belt assembly to be used by the child (3).

These regulations were based, to a significant degree, on previous work conducted at DCIEM for Transport Canada (4, 5). Consequently, Transport Canada requested that the Impact Studies Facility at DCIEM conduct and evaluate simulated impacts, using the HyGe crash simulator, in order to determine if all the infant and child carriers which were currently being marketed in Canada met the requirements of the new regulations. As the first phase of a two-part program, this report concerns the testing of infant carriers only.

2. Test Equipment and Instrumentation

The tests were performed on the DCIEM 12-inch HyGe impact accelerator (Bendix Corp.), which simulates impact by rapid acceleration. The crash deceleration pulse which was delivered to the test package was programmed by the adjustment of various gas pressures and

volumes within the impact accelerator, and by the selection of a suitably-shaped internal metering pin. The test sled, with its payload, was accelerated to a pre-determined velocity in a backwards direction. During this short period of rapid acceleration, the payload experienced the same dynamic loads that would occur during a sudden decelerative crash. After the initial acceleration, the sled was slowly decelerated to a stop.

The deceleration pulse used for this particular test was specifically designed to meet Transport-Canada requirements for the dynamic testing of automotive infant carriers, as given in Reference 6. Two additional requirements imposed by Transport Canada were that the acceleration profile should be confined below the line shown in Figure 1 (which is taken from Reference 6) and that the change in velocity lie between 28.50 and 29.75 miles per hour (mph). For pulse measurement purposes, the basic sled acceleration data were monitored using two Setra, model 14, high-output acclerometers, which were mounted directly on the impact sled.

In each test, the infant carrier was positioned in the center of the "standard bench seat" which was fastened to the HyGe impact sled, and is described in the United States National Highway Traffic Safety Administration's (NHTSA's) drawing package No. NHTSA-SAS-100-1000, as called for by Transport-Canada regulations (2). This seat, which is shown with an infant carrier in Figure 2, was designed by the Highway Safety Research Institute at the University of Michigan, and was constructed in order to meet the precise and extensive specifications laid down by the NHTSA. It is used throughout the automotive industry for child-carrier, and other, dynamic tests. Since the child carrier was center-mounted, only the two center, inner-seat anchorage points of the four available on the bench seat were used to secure the child carrier.

The extensive specifications* for the construction of this seat require the use of two pairs of special foam slabs, one pair for the seat-back cushion, and a different pair for the seat-bottom cushion. A number of these slabs were made up specially for this test series, since Transport Canada requested that any pair of seat-back cushions and seat-bottom cushions be used for only five and three tests, respectively, before being discarded. Also, all the foam was to be removed from the vinyl seat-covers after each test, and allowed to recover for at least 24 hours before being used again.

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* These specify the density, indent load, indent load ratio (defined as the ratio of the amount of vertical load required to indent a specified probe 65%, and then 25%, into a slab of foam), tensile strength, elongation, tear resistance, compression set, and humidity content that must be met by the foam slabs.

The occupant of the child carrier was the 6-month-old infant crash-test dummy shown in Figure 3 (Alderson Research Labs, Stamford, Connecticut, U.S.A., CAMI type), which conforms to the United States Code of Federal Regulations (7). This dummy represents a 50th-percentile, 6-month-old infant, with a weight between 17 and 18 pounds, and a sitting height of approximately 17.5 inches.

For visual data gathering, two ruggedized, high-speed Stalex rotating-prism motion-picture cameras were mounted on two outriggers, one on each side of the bench seat, providing lateral views of each side of the carrier and bench seat. These cameras were equipped with 13-mm wide-angle lenses, and operated at a speed of 1000 frames per second.

Two Graph-Check sequence cameras were also set up, in order to provide "quick-look" photographs of events during the impact. These cameras take eight separate photographs, at pre-selected equal intervals, on a single sheet of Polaroid film which is available for viewing immediately after the impact.

3. Data Recording and Processing

Sled inertial data were obtained from accelerometers on board the sled using a series of specially-designed, ruggedized, low-noise preamplifiers to increase the signal strength. The signals were analog-filtered at 5 kHz on board the sled, and were then transmitted along a low-noise, flying-lead, umbilical cable to the recording and data reduction area, where they were stored in the memories of a multi-channel transient recorder (Datalab, Surrey, U.K.). The transient recorder equipment digitized the input signal at a sampling rate of 10 kHz. The digitizer accuracy was 10 bits (1 part in 1024), and the total recording time of the digitized data was 0.4 seconds. Complete details of the Impact Studies Facility's data acquisition system can be found in Reference 8. The specifications of the digitizing and recording equipment are more stringent than those established by the Society of Automotive Engineers (SAE), which sets instrumentation standards for dynamic testing purposes (9).

Immediately after firing the sled, the data were transferred to a computer disk for processing. (The raw data for all runs are being retained on magnetic tape in the DCIEM computer center on an indefinite basis.) The computer programs first performed digital filtering on the data, according to the SAE specification (9) which details the specific filtering to be carried out on signals emanating from various sources. For this test, only sled acceleration was recorded, and it was filtered, as specified, at 60 Hz. The data were then scaled and the velocity computed, by successive integration of the sled acceleration. Finally, appropriate graphs were produced by a plotter under computer control.

Information on carrier movement and dummy excursion was obtained from the movie films through the use of a commercially-available film-reader, which allows single frames to be viewed, and X-Y positions, or angular changes in targetted carrier/dummy sites to be determined manually.

4. Test Requirements and Methodology

Complete requirements for the tests are specified in CMVSS 213.1, sub-parts 9 through 12, inclusive, and are reproduced in Appendix A(2). The following is a description of the contents of subparts 9 through 12, along with brief comments on the testing procedure used for each requirement; any deviations from the test method which were found necessary are also noted.

Loaded Buckle Release Force (sub-part 9)

This determination requires the attachment of one portion of a sling to each ankle and wrist of the infant dummy after it has been seated in the carrier, facing rearward, as specified by the manufacturer for infant seating. The sling is pulled horizontally, in line with the center-line of the seat assembly, with a force of 20 pounds, and the buckle-release mechanism is then activated in order to release the harness, as instructed in Reference (6), and by further regulations in Transport Canada's Motor Vehicle Safety Test Methods, Section 209, "Seat Belt Assemblies" (10). The pre-impact force required to release the buckle must be greater than 8 pounds, while the post-impact force must be less than 16 pounds.

This test was performed as stated; but with the infant carrier facing the front of the bench seat, since it is physically impossible to pull on the sling and measure the buckle release force when the carrier is facing the rear, because of the seat back. Also, for the buckle release force, only the last half of the relevant section in the test methods for seat-belt assemblies was followed (10); specifically, sub-part 2.2.4(a), excluding the first two sentences concerning belt loading, which was not required by Transport Canada.

The device used to apply the 20-pound pull on the infant dummy was a linear spring scale made by Chatillon (model LN-25); while the buckle release force was measured with a mechanical force gauge made by Hunter-Spring (series "D" type), and supplied by Transport Canada.

These loaded-buckle release tests, and the unloaded-buckle release tests described below, are always very difficult to perform. Consistent, repeatable data are not easily obtained on account of several experimental parameters which are not readily controlled.

Procedural problems resulted from: rough, poorly-fitting tongues and their mating parts in the buckles; irregular buckle-release actions; interference and friction between the dummy and carrier surfaces, belts, etc.; physical/space problems associated with measuring the release forces on essentially-unsupported buckles in confined, difficult-to-access areas; tongues which would not spring out of their buckles, unassisted, at any release force; and the tendency of the 20-pound sling force to press the dummy against the carrier bottom, rather than move it out of the carrier (thus loading the buckle), as was undoubtedly the original intention. In practise, it was necessary to use a trial-and-error approach when first measuring the release force with a new carrier, until minimal and maximal release forces were obtained, for pre- and post-impact measurements, respectively.

Unloaded Buckle Release Force

This test is not part of CMVSS 213.1, but was requested by Transport Canada in order to supplement the above findings. The pre-impact buckle release force is measured without a dummy in the carrier, and with the carrier in any convenient attitude. Since most buckles do not spring apart when the release mechanism is depressed, it was found necessary to apply a one-pound pull force to the tongue of the buckle during this test, so that the buckle and tongue would separate. Also, it was noted that, for some buckles with two independent tongues, one tongue tended to pull out of the buckle before the other; in such cases, the release force for each tongue was noted. The buckle release force, and the one-pound pull force, were both measured using mechanical force gauges, made by Hunter-Spring (series "D" and "C" types, respectively) and supplied by Transport Canada.

Structural Integrity Test (sub-part 10(a))

This regulation sets limits on the maximum-allowable size of any protrusions which may occur, and the amount of structural separation of seat elements allowed, during impact. By agreement with Transport Canada, the requirements of this regulation were modified so that partial separations with specified edge radii or protrusions were considered relevant only if they occurred in any interior area of the seat which could make contact with the infant.

Integrity of the Adjustment Position (sub-part 10(b))

This regulation concerned only those carriers which allow two or more adjustable positions for altering the angle of the carrier back. (One particular position is normally specified for use in

moving automobiles.) If the adjustment position changes during or after the impact, the carrier fails this regulation.

Occupant Excursion (sub-part 10(c))

There are two requirements in this regulation, which apply during and after impact; the target point specified on the head of the infant dummy must not pass through the transverse vertical plane which passes through (a) the forwardmost point on the top of the infant carrier; and (b) the most rearward point at the top and backside of the bench-seat back. (The latter requirement concerns the motion of the carrier after the impact, when the carrier and infant may rebound and be stopped by the back of the bench seat. Under certain conditions, it is possible for the infant and/or the carrier to be pitched a short distance over the top of the seat back.)

For this evaluation, two Stalex high-speed motion-picture cameras were placed on outriggers mounted on each side of the sled, opposite the carrier. The views from the two cameras, identified as "right" and "left", respectively, are shown in Figures 4 and 5. Both photographs are enlargements from high-speed 16-mm movie films, and show the typical maximum forward carrier rotation and excursion during impact (right camera); and the typical maximum rearward "rebound" carrier excursion after impact (left camera). The right camera was positioned to show the location of the head target and the degree of rotation of the entire carrier at all times during the impact, thereby meeting the requirements for (a) above, and, also, for another requirement described below (see sub-part 10d). In order to satisfy requirement (b), the left camera was initially positioned to sight along an imaginary line which represents the location of the uppermost rear edge of the bench seat after impact, as shown in Figure 5. Note that the seat-back is pivoted at its bottom, and is designed to rotate forward about 8 degrees, or 3.5 inches, at its top during impact, because of its own inertia. Therefore, before impact, the left camera sights along a line about 3.5 inches in front of the static seat-back position.

After impact, the films from the two cameras were reviewed on a film-reader. Reference lines on the sled in each frame helped to establish the appropriate vertical planes for the film-reading.

Back Support Angle (sub-part 10 (d))

This regulation requires that the angle between the carrier seat-back, at a specified point on the interior surface of the carrier back and the vertical, must not be greater than 70 degrees at any time during the impact; i.e., the amount of rotation of the carrier must fall within a specified limit.

d. attach the infant restraint belts around the dummy to the required tension.

Since it was usually impossible to perform (c) after (b), because of interference from the bench seat lap-belt, these steps were rearranged as follows:

a. set the carrier onto the bench-seat;
b. place the infant dummy into the carrier;
c. attach the infant restraint belts around the dummy to the required tension; and
d. tighten the bench seat lap-belt around the carrier to the specified tension.

Also, section 2.4.2(c) specifies that the dummy must be installed into the carrier according to the manufacturer's instructions for child positioning, rather than those for infant positioning; however, the latter positioning procedure was used throughout the tests.

5. Results

The plots of the sled acceleration for each carrier test are given in Appendix C. As required by Transport Canada, each acceleration pulse lies below the line shown in Figure 1, which is taken from Reference (6). The peak acceleration for each test, and the maximum velocity attained (by integration of the acceleration plot) are given at the top of Table 1 under the heading "Test Conditions", along with other pertinent test and laboratory parameters (specifically, ambient temperature and relative humidity) for which specifications are given in Reference (6). All four of the test and laboratory parameters were confined within the required specification for each of the twelve HyGe sled firings performed.

The results of each compliance requirement for each of the carriers is presented in the lower portion of Table 1. This table gives the title of each particular compliance test (as described in section 4), the sub-part in CMVSS 213.1 from which each originates, and the exact condition which must be satisfied in each test for compliance. Failure to comply with a test is identified by an "X" in the appropriate column. The measured values (of force for the buckle tests, and of degrees for the back-support angle) have been included, where applicable.

Table 2 identifies the carriers and shows the set-up data relevant to the test series. Included are (a) the number assigned to the carrier (for identification and photographic use), (b) the carrier name, (c) the model number, (d) the carrier adjustment position which Transport Canada specified should be used in the test, and (e) the

back-support angle,* which is not required for any of the compliance tests, but which might be useful in verifying the adjustment position which was used in the tests.

The tests identified only two carriers which failed to fully meet the compliance criteria, and each failed only one compliance requirement. Carrier No. 5 failed the pre-impact, loaded-buckle release-force test, by releasing the buckle at 6.5 pounds, while compliance required a force in excess of 8 pounds. The other was the failure of seat No. 1 to pass the requirement for "integrity of adjustment position". This seat changed its adjustment position by one notch setting during the impact, causing the carrier to rotate to its maximum possible vertical attitude. This latter position is not recommended by the manufacturer for infant restraint in moving automobiles. The test was repeated with a new, identical carrier (designated No. 2), which verified the compliance failure.

6. Conclusions

Of the eleven different infant carriers which were subjected to the simulated impact, all but two carriers successfully met the requirements set out in CMVSS 213.1. The two failures were for insufficient, pre-impact, loaded-buckle release force in one carrier (No. 5); and a change in the adjustment position during impact, in a different carrier (No. 1). The buckle release tests were, in general, difficult to perform in a manner that would produce consistent, repeatable results. In this respect, the buckle release test is not a totally fair test for all seats. It is felt that this test and its procedures should be redesigned before this particular portion of CMVSS 213.1 is fully enforced. However, the test for the integrity of the adjustment position involves no difficult or uncertain steps, and can be performed easily with consistent results. This is demonstrated by the identical adjustment position failure which occurred during both of the tests with the same model carrier (Nos. 1 and 2).

For this test series, Transport Canada made a number of changes to the regulations within CMVSS 213.1 (2), the laboratory procedures in the Motor Vehicle Safety Test Methods, Section 213.1, "Infant Seating and Restraint Systems" (6), and the Motor Vehicle Safety Test Methods, Section 209, "Seat Belt Assemblies" (10). Also, many of the laboratory procedures were incorrectly stated, lacking sufficient detail, or absent. Appendix D gives a complete listing of all the relevant changes and discrepancies, and, also, the amendments which DCIEM recommends should be made to the Regulations and Test Methods.

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* This is defined as the angle between the carrier seat-back, at a specified point, and the vertical, with the seat on a horizontal surface, correctly adjusted for dynamic testing.

References

1. "Children Car Seats and Harnesses Regulations", chapter 921 of the Hazardous Products Act, Consumer and Corporate Affairs, 1978

2. "Infant Seating and Restraint Systems", Canadian Motor Vehicle Safety Standard 213.1, Transport Canada, September 1, 1982

3. "Booster Cushions", Canadian Motor Vehicle Safety Standard 213.2, Transport Canada, March 9, 1983

4. Child Restraint Dynamic Test Program. Unpublished test program carried out for the Road and Motor Vehicle Traffic Safety Branch of Transport Canada, 1981

5. WILLIAMS, C.B., J.K. REICHERT, and P.Y. DIONNE, "Task Force Report to the Minister of Consumer and Corporate Affairs Canada on Crash Protection for Infant and Child Passengers in Motor Vehicles", Consumer and Corporate Affairs, Jan 1980

6. "Infant Seating and Restraint Systems", Motor Vehicle Safety Test Methods, Section 213.1, Transport Canada, July 19, 1982

7. "Part 572 - Anthropomorphic Test Dummies," in Code of Federal Regulations, Title 49: Transportation, The Office of the Federal Register, National Archives and Records Service, General Services Administration, Washington, DC. U.S.A, sub-part D, 438-439, 1981 (49CFR 572)

8. BOWDEN, T.J., J.K. REICHERT, and J.P. LANDOLT, "The Data Acquisition System at the DCIEM Impact Studies Facility," in Passenger Car Meeting, Society of Automotive Engineers, Inc., Warrendale, PA, U.S.A., June 8-12, 1981. (SAE Paper No. 810812)

9. "SAE Recommended Practice J211 1980 - Instrumentation for Impact Tests", Society of Automotive Engineers Inc., Warrendale, PA, U.S.A., 1980.

10. "Seat Belt Assemblies", Motor Vehicle Safety Test Methods, Section 209, Transport Canada, June 1, 1978

11. Correspondence with Mr. M. Dance, Road and Motor Vehicle Traffic Safety Branch, Transport Canada, February 24, 1983

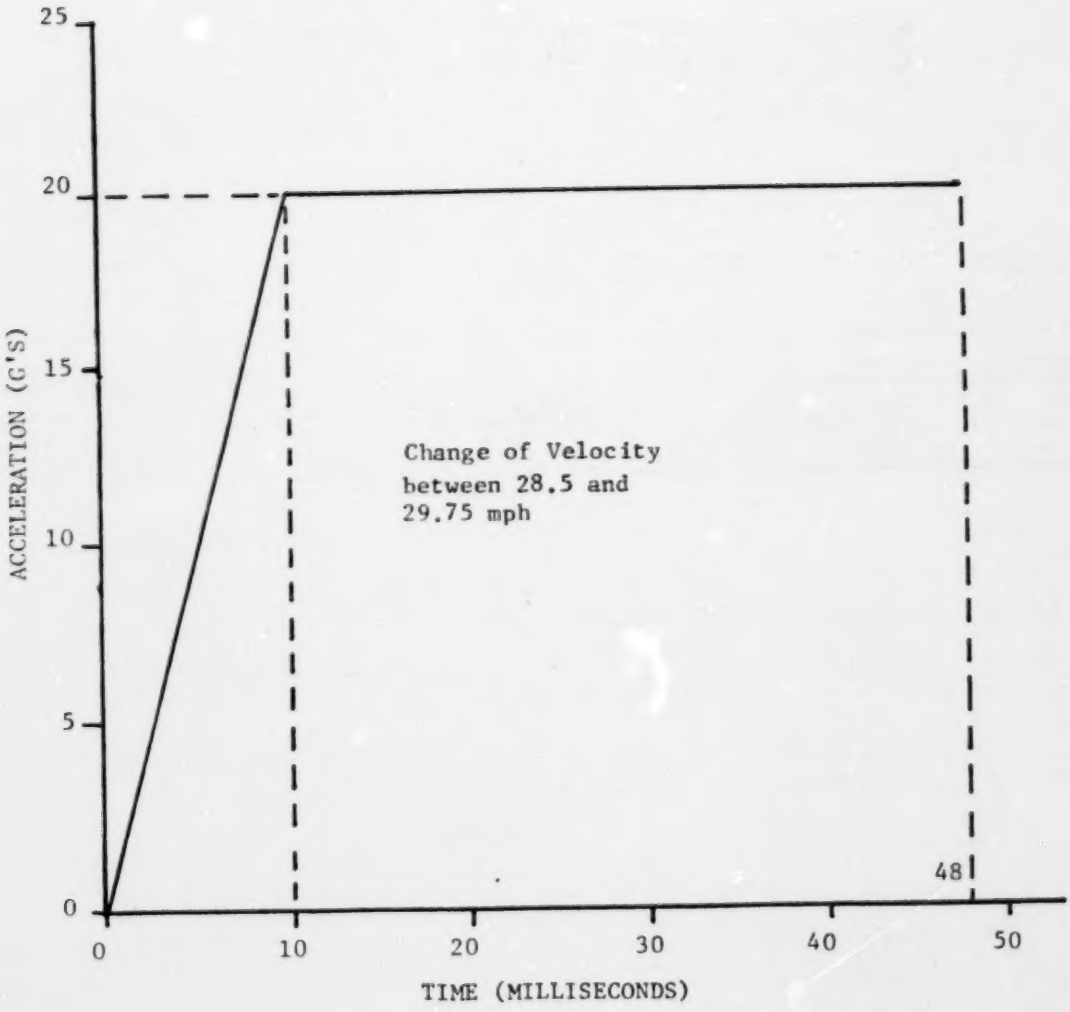


Figure 1: Specification for Test Platform Acceleration, as per MVSTM 213.1

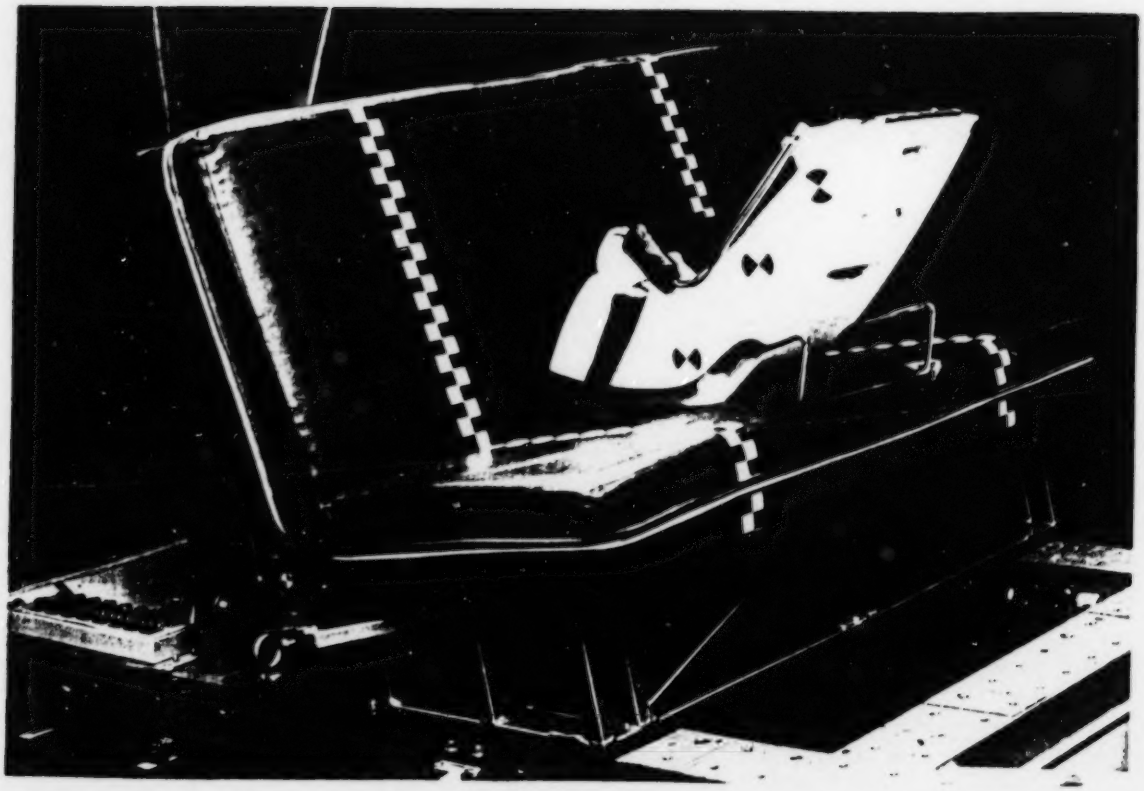


Figure 2: Standard Bench Seat on Sled, with Carrier and Infant Dummy

Figure 3: Six-Month Old Infant Dummy

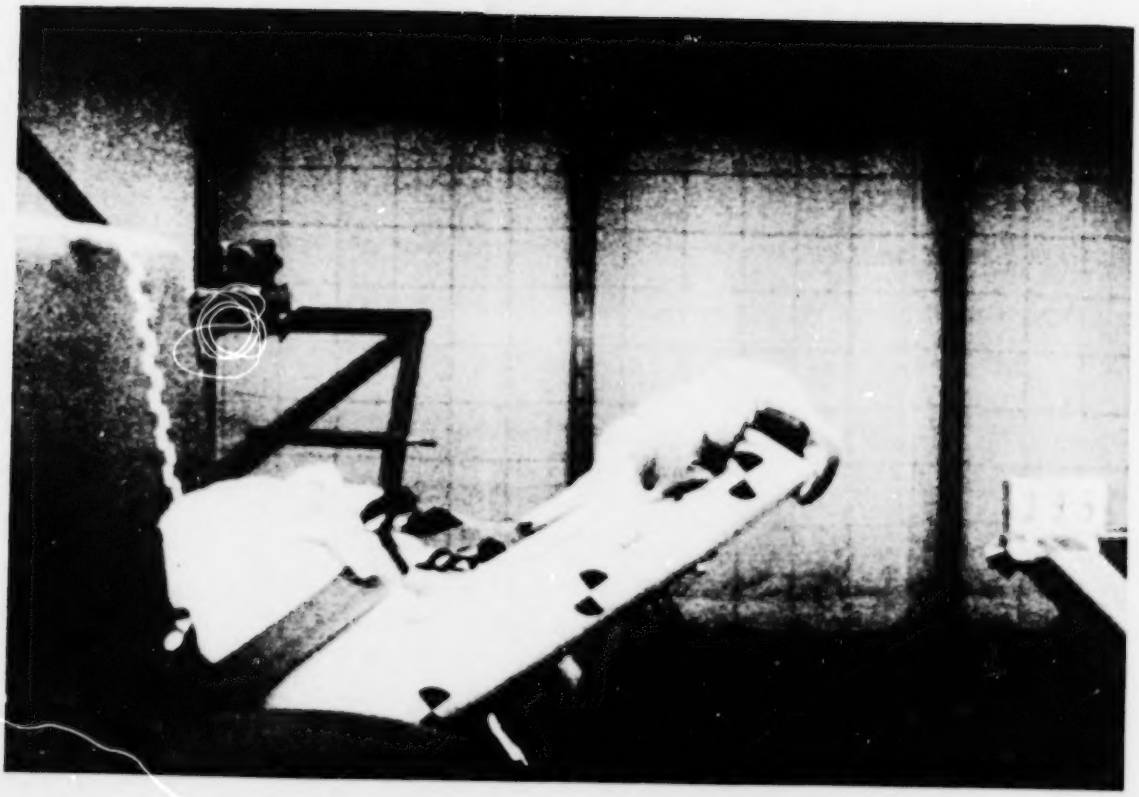


Figure 4: View of Seat Bench from the Right Lateral Movie Camera

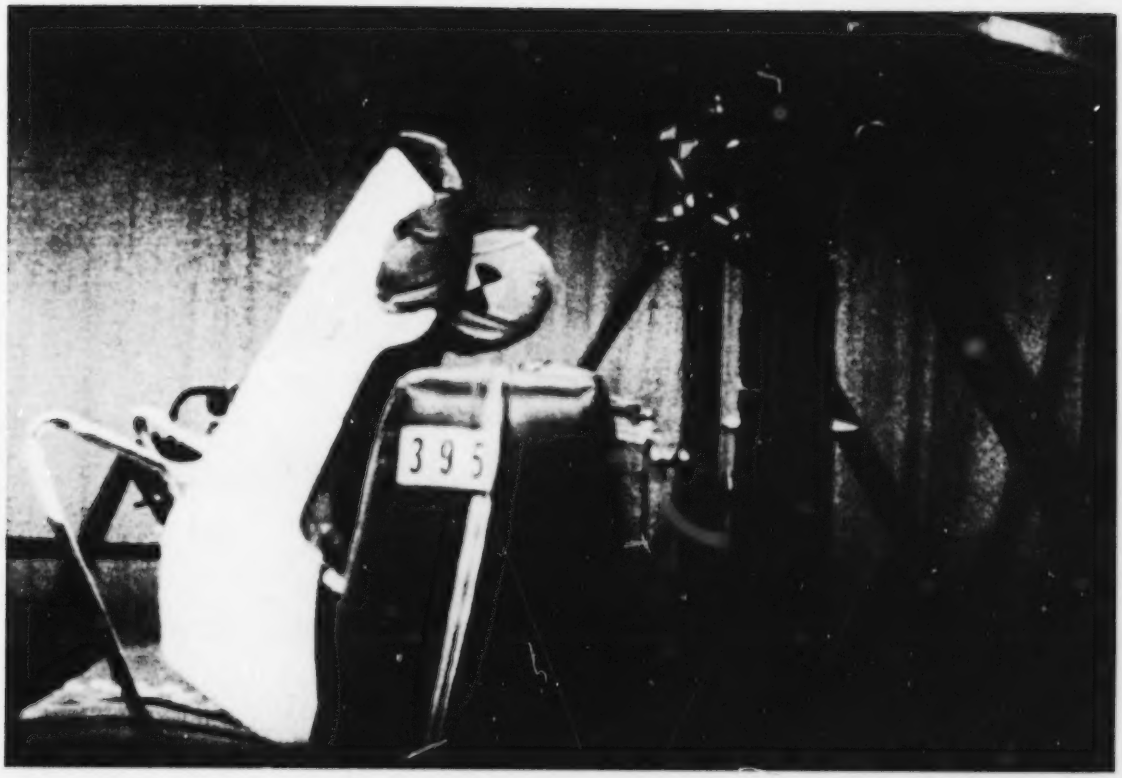


Figure 5: View of Seat Bench from the Left Lateral Movie Camera

TABLE 1: COMPLIANCE TEST CONDITIONS AND RESULTS

	COMPLIANCE REQUIREMENT	TEST RESULTS — CARRIER NUMBER											
		1	2	3	4	5	6	7	8	9	10	11	12
TEST CONDITIONS													
Ambient Temperature	66 - 78 (degrees F)	74	76	74	73	71	73	72	73	74	72	72	71
Relative Humidity	10 - 70 (%)	43	31	33	34	25	24	38	38	29	34	34	25
Peak Acceleration	20 (G)	19.5	19.9	19.4	19.4	19.7	19.4	19.7	19.5	19.4	19.4	19.4	19.4
Change in Velocity	28.5 - 29.75 (mph)	29.2	29.4	29.1	29.1	29.3	29.1	29.4	29.3	29.2	29.1	29.3	29.2
COMPLIANCE REGULATION Unloaded-Buckle Release Force	None (pounds)	10	10.5	13.5 / 20	12.5 / 15	6	10.5	12	(1)	14.5	15.5	17.5 (2)	10
CMVSS 213.1(9): Loaded-Buckle Release Force	(i) Pre-Impact Force 8 pounds (pounds)	10.5 P	11.7 P	14.2 P	15 P	6.5 F	11 P	13 P	(1)	17.5 P	14.5 (4)P	(3)	11 P
	(ii) Post-Impact Force 16 pounds (pounds)	12 P	10 P	15 P	14.5 P	6 P	10 P	11.5 P	(1)	14.5 P	12.5 (4)P	(3)	10.5 P
CMVSS 213.1 (10a): Structural Integrity	(i) No complete separation	P	P	P	P	P	P	P	P	P	P	P	P
	(ii No partial separation with exposed edge radius 1/4"	P	P	P	P	P	P	P	P	P	P	P	P
	(iii) No partial separtion with	P	P	P	P	P	P	P	P	P	P	P	P
CMVSS 213.1 (10b): Adjustment Integrity	No change	F	F	P	P	P	P	P	P	P	P	P	P
CMVSS 213.1 (10c): Occupant Excursion	(i) Head target not beyond forward point	P	P	P	P	P	P	P	P	P	P	P	P
	(ii) Head target not beyond rear point	P	P	P	P	P	P	P	P	P	P	P	P
CMVSS 213.1 (10d): Back Support Angle	Angle 70° (degrees)	43 P	40 P	51 P	53 P	42 P	45 P	43 P	52 P	42 P	40 P	64 P	60 P

P indicates successful compliance test; F indicates failure
(1) not applicable, since this carrier has no buckle
(2) the pullout force was raised to 5 pounds to effect pullout here
(3) unusual buckle geometry prevented this test
(4) a small pullout force was required to effect pullout here

TABLE 2: CARRIER DATA

CARRIER NUMBER	CARRIER NAME	MODEL	ADJUSTMENT POSITION	BACK SUPPORT ANGLE (degrees)*
1	Dyn-O-Mite Infanseat	441C	second last notch postion	40
2	Dyn-O-Mite Infanseat	441C	second last notch position	41
3	Bo-Peep	19040	no adjustment possible	33
4	Bo-Peep Hi-Rider	19030C	lever in lowest position	34
5	Dorel	779	lever in lowest position	36
6	Dorel Safe-T-Ryder	339	lever in lowest position	38
7	Collier-Keyworth Safe and Sound	---	reclined position	39
8	Infant Loveseat	4500	no adjustment possible	35
9	Cosco/Peterson Safe-T-Shield	81	lever in lowest position	30
10	Cosco/Peterson Safe-T-Seat	78	lever in lowest position	30
11	Cosco/Peterson First Ride	---	third last notch position from the vertical	53
12	Strolee	C599	between "package" and "child" positions	26

* This is the angle betwen the carrier seat-back at a specified point, and the vertical, using the method given in Appendix B, with the seat on a horizontal surface in its correct adjustment position for dynamic testing.

Appendix A

Buckle and Dynamic Test Requirements
from CMVSS 213.1 "Infant Seating
and Restraint Systems

(9) Any buckle in an infant restraint system belt assembly designed to restrain the infant shall not release when a force of less than 35 N (8 pounds) is applied before dynamic testing and shall release when a force of not more than 70 N (16 pounds) is applied after dynamic testing in accordance with Motor Vehicle Safety Test Methods, Section 213, "Child and Infant Seating and Restraint Systems", (April 1, 1982).

(10) Every infant restraint system shall be so designed and constructed that in an impact simulation carried out in accordance with Motor Vehicle Safety Test Methods, section 213, "Child and Infant Seating and Restraint Systems", (April 1, 1982)

(*a*) no complete separation of any load bearing structural element and no partial separation exposing either surfaces of the infant restraint system with a radius of less than 6,4 mm (¼ inch) or surfaces with protrusions greater than 9.5 mm (⅜ inch) above the adjacent surrounding contactable surface of any structural element occurs;

(*b*) the infant restraint system remains in the same adjustment position throughout the impact simulation;

(*c*) movement of the anthropomorphic test device is so restricted that the target point on the head of the test device does not at any time during and immediately after the impact simulation, pass through the transverse vertical plane passing through

(i) the forward most point on the top of the infant restraint system (see Fig. 2), and

(ii) point X on the standard seat (see Fig. 3); and

(*d*) the angle between the back and head support surface, measured 240 mm (9.4 inches) above the seat surface, and the vertical shall not be greater than 70 degrees at any time during the impact simulation.

(11) The seat used in the impact simulation shall be the dynamic seat assembly described in drawing package NHTSA-SAS-100-1000 (see Fig. 1).

(12) Every infant restraint system in which the position of the infant is adjustable shall meet the requirements of subsection (10) at each adjustment position that the manufacturer has not specifically warned against using in motor vehicles in accordance with paragraphs (13)(*f*) and (16)(*b*).

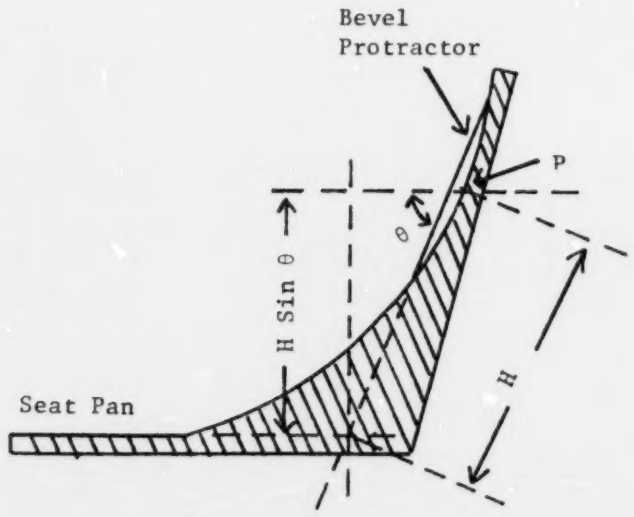
Appendix B

Determination of the Carrier
Back Support Angle

Transport-Canada Regulation 10(d) in CMVSS 213.1 requires that "the angle between the back- (and head-) support surface, measured 9.4 inches above the seat surface, and the vertical" be measured during impact simulation tests. Since the "9.4 inch" measurement is not well defined, and since carrier backs are often curved, and have a poorly defined intersection with the carrier bottom, the following method was devised in order to better define and determine:

a. the point at 9.4 inches specified in the Regulations; and
b. the angle that an approximated tangent line to this point makes with the vertical.

As shown in the sketch below, with the infant carrier propped up so that the seat pan (i.e., the interior of the carrier seat bottom) is horizontal, the angle of the inner back at any location "P" can be closely approximated by placing the flat face of a bevel protractor* against the inside seat-back material. The distance, "H", between the center of the device on the seat back at "P" on the incline from the horizontal extension of the interior carrier bottom, should be specified by CMVSS 213.1 10(d) in Transport-Canada Regulations.



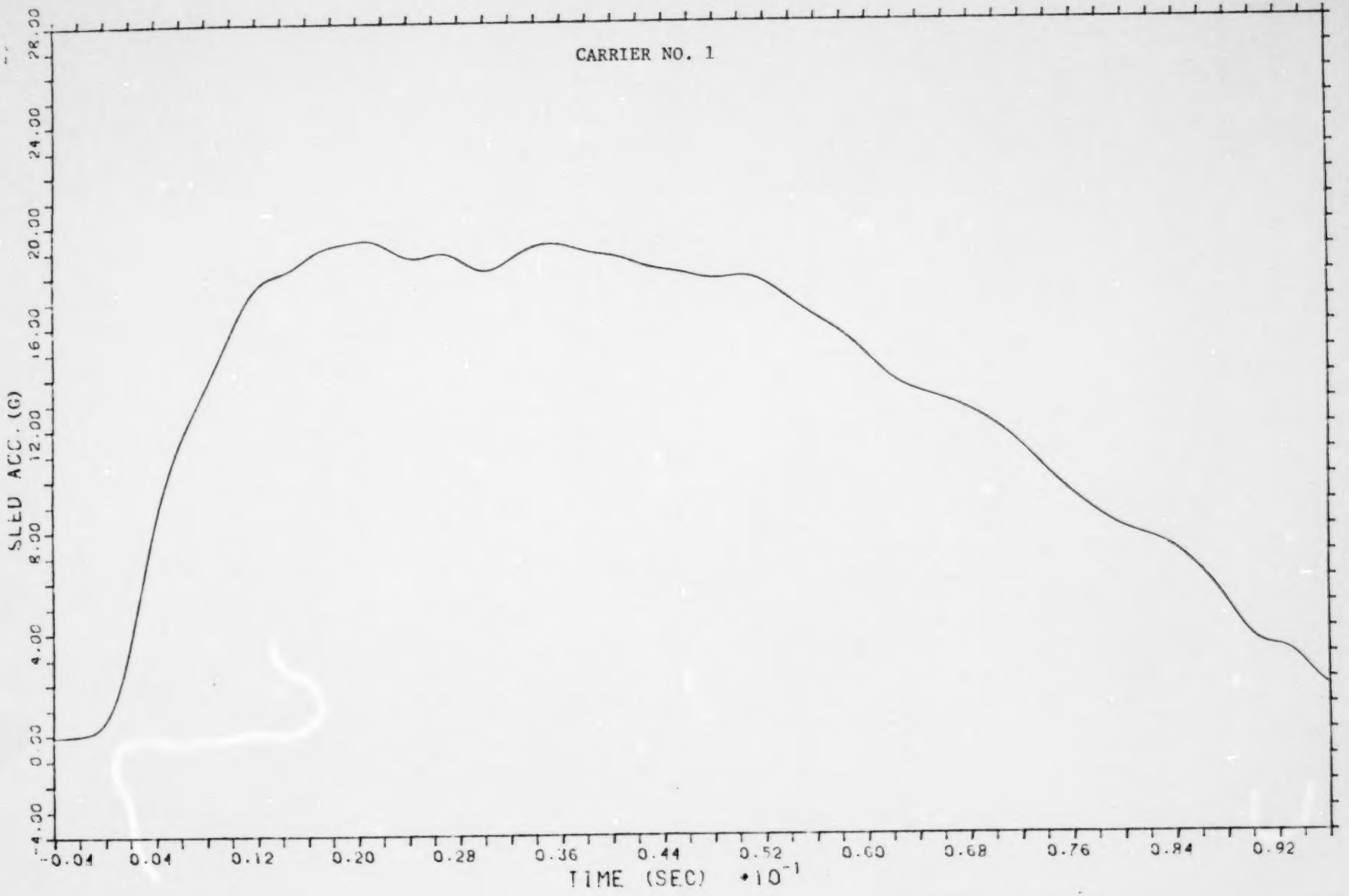
* This device has a 7-inch long flat face to which is attached a bubble tube which can be rotated 360°, and allows angular measurements to be taken with an accuracy of ± 1/2°.

This distance is implied to be 9.4 inches in the current regulations, if "above the seat surface" in sub-part 10(d) is interpreted to mean "on the incline". In this new procedure, therefore, the angle of a chord centered across the specified point on the interior of the seat would be determined, instead of the angle of a tangent to the specified point, which cannot be determined for many carriers, the back exteriors of which are enclosed or otherwise encumbered.

After making an initial quess as to the location of "P" and determining the angle "θ", the vertical elevation of "P" above the carrier seat bottom can be calculated (= H Sin θ) and the location of "P" checked with a scale mechanism. If in error, one or two more simple iterations will locate "P" with sufficient accuracy: (for straight backs, no iterations are required). A line, or two targets representing a line, can then be added to the exterior of the seat at the required angle, θ, representing the carrier back angle, for film analysis purposes.

Appendix C

Sled Acceleration Plots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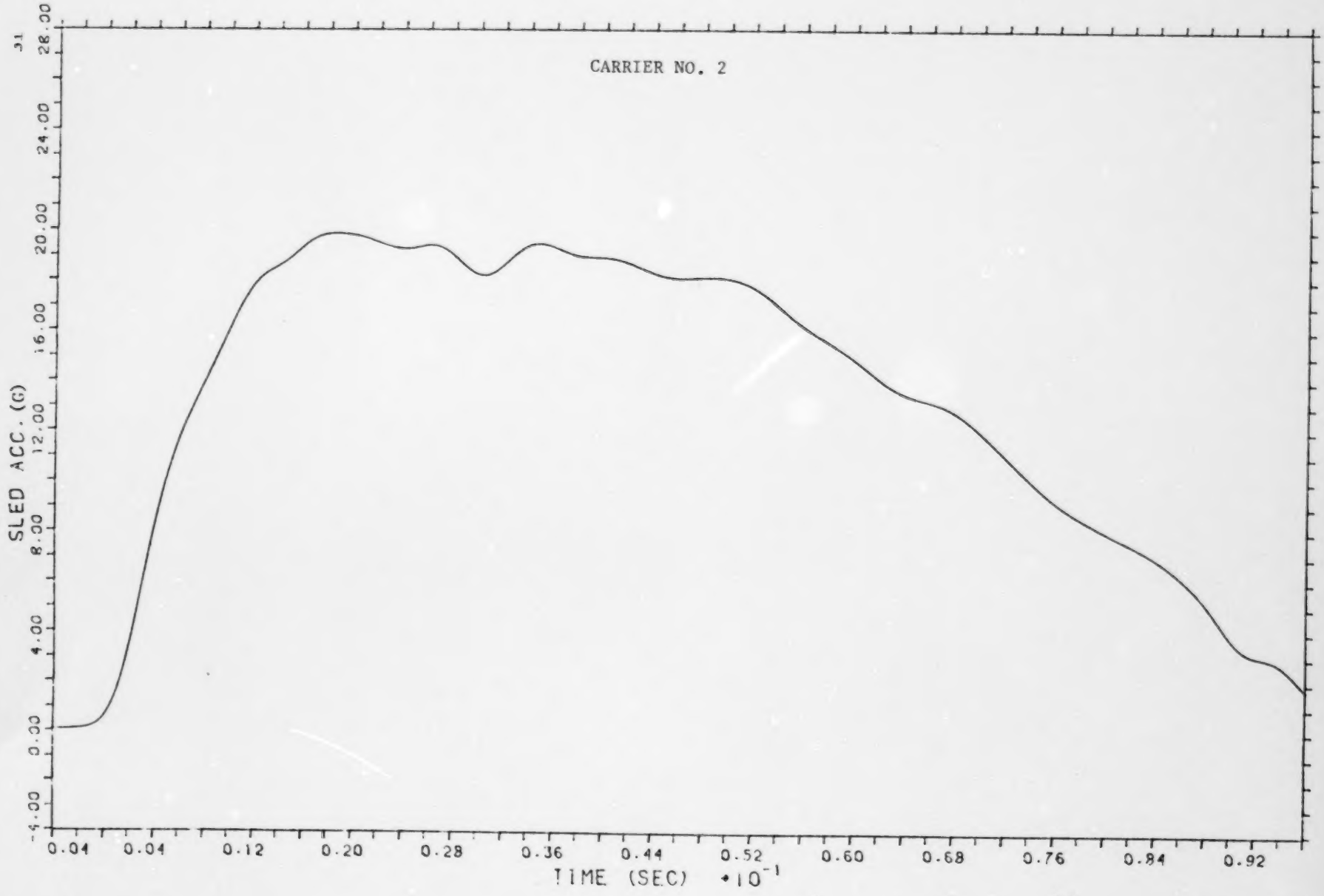
4.00
8.00
12.00
16.00
20.00
24.00
28.00
-0.04
0.04
0.12
0.20
0.28
0.36
0.44
0.52
0.60
0.68
0.76
0.84
0.92
TIME (SEC) •10⁻¹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0.04
0.04
0.12
0.20
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0.36
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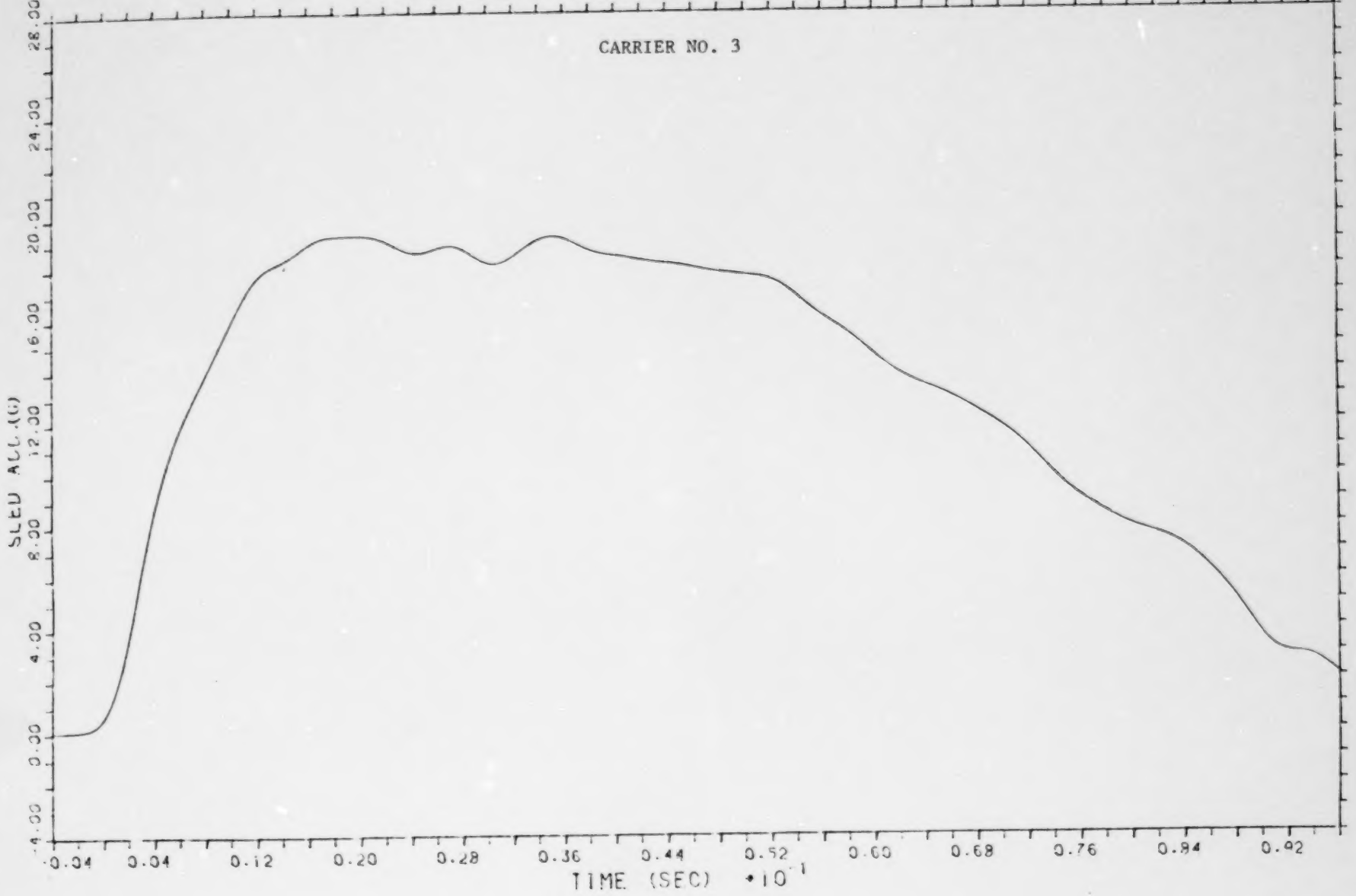
0.52
0.60
0.68
0.76
0.84
0.92
TIME (SEC) *10^-1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0.00
0.04
0.12
0.20
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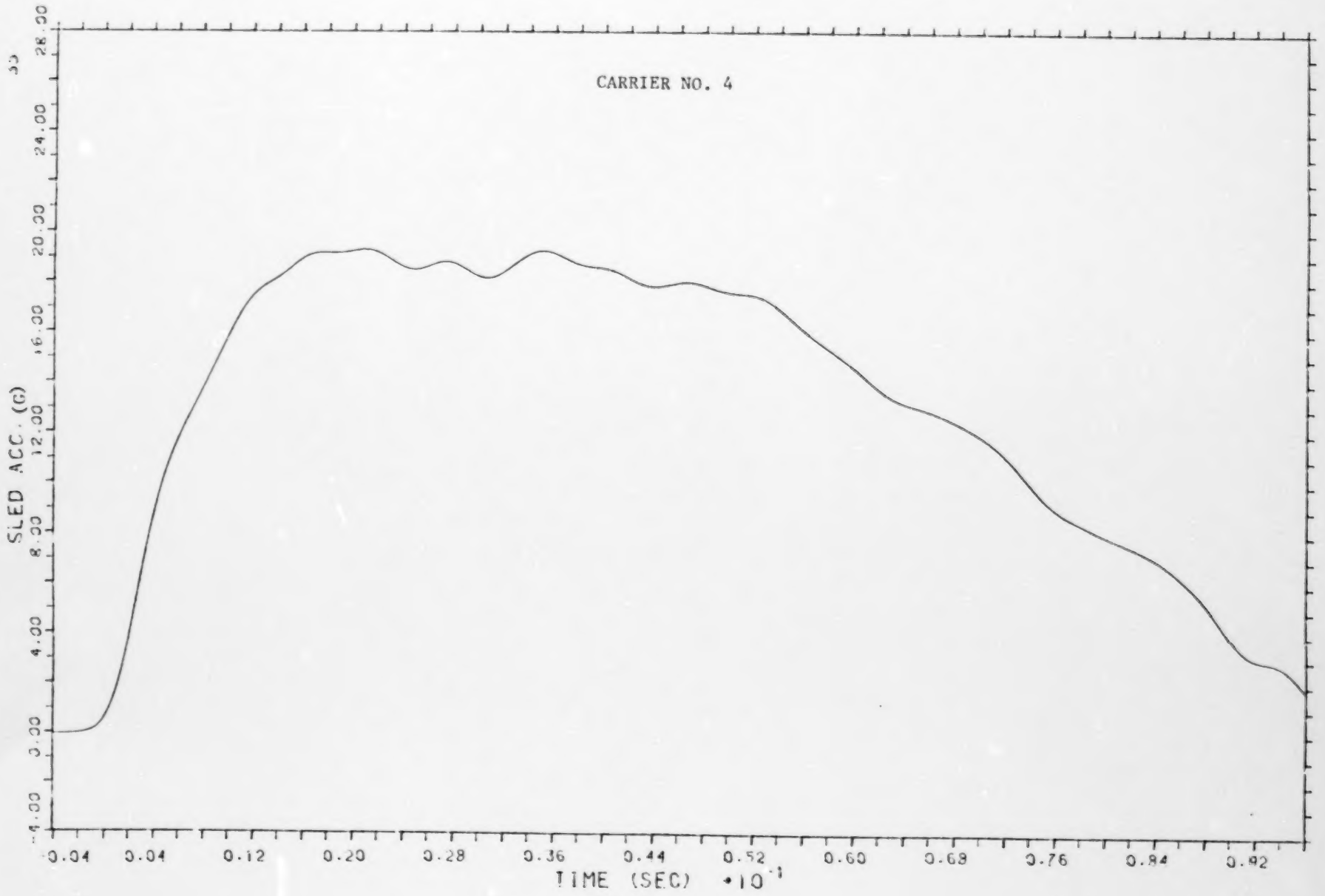
0.36
0.44
0.52
0.60
0.68
0.76
0.84
0.92
TIME (SEC) *10^-1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12.00
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4.00
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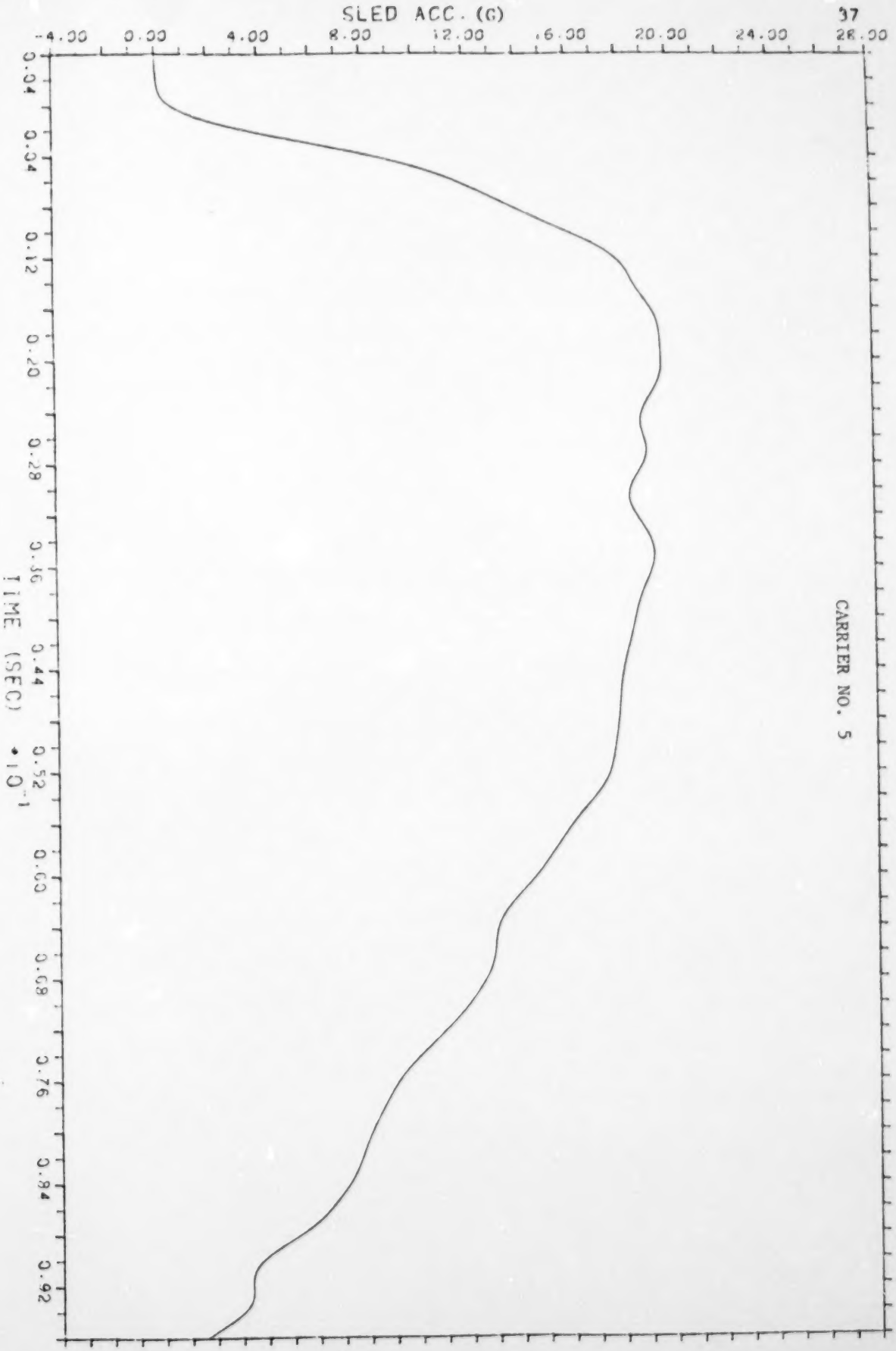
-4.00
0.04
0.04
0.12
0.20
0.28
0.36
0.44
0.52
0.60
0.68
0.76
0.84
0.92
TIME (SEC) *10^-1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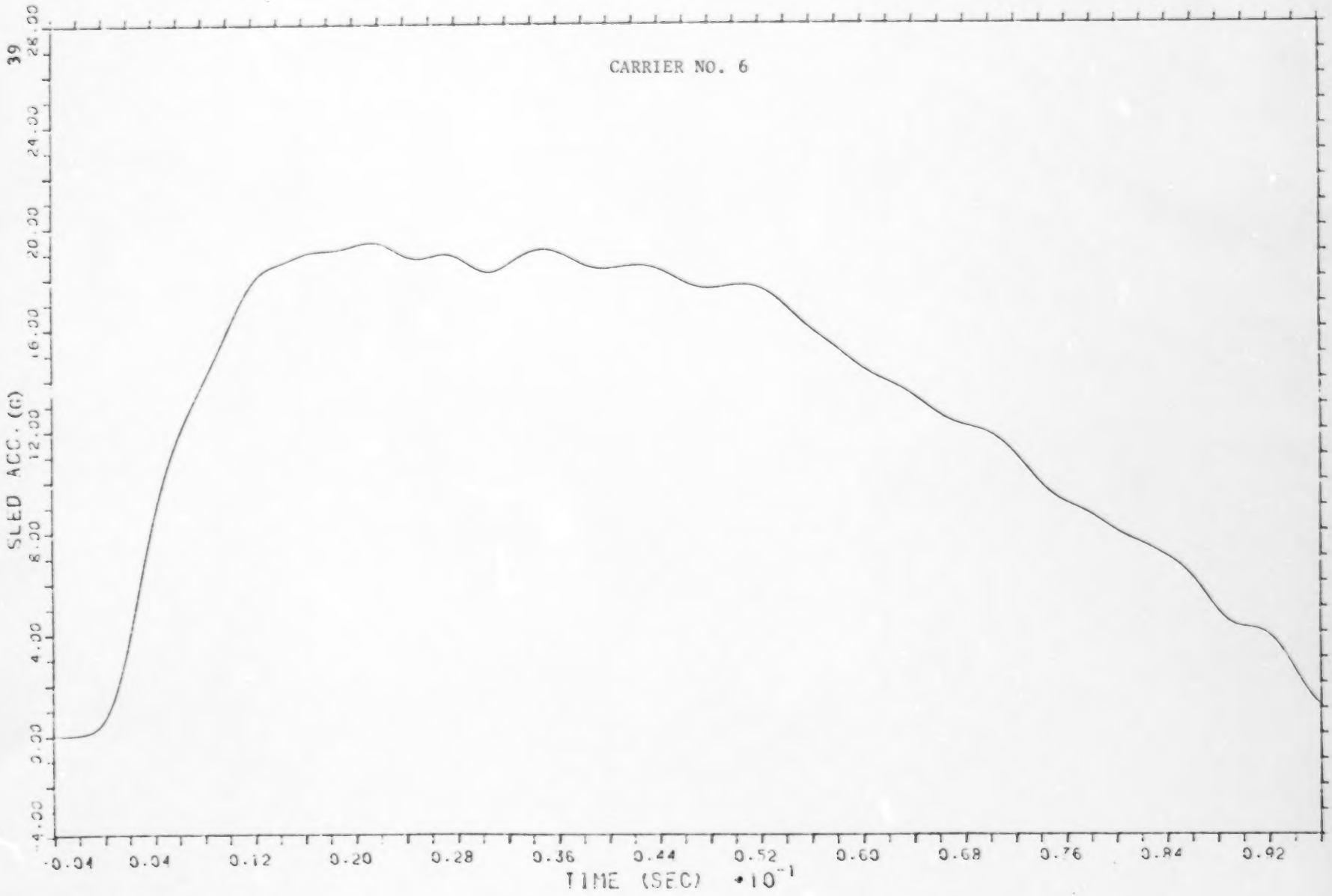
12.00
16.00
20.00
24.00
28.00
0.04
0.04
0.12
0.20
0.28
0.36
0.44
0.52
0.60
0.68
0.76
0.84
0.92
TIME (SEC) *10-1
CARRIER NO. 5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4.00
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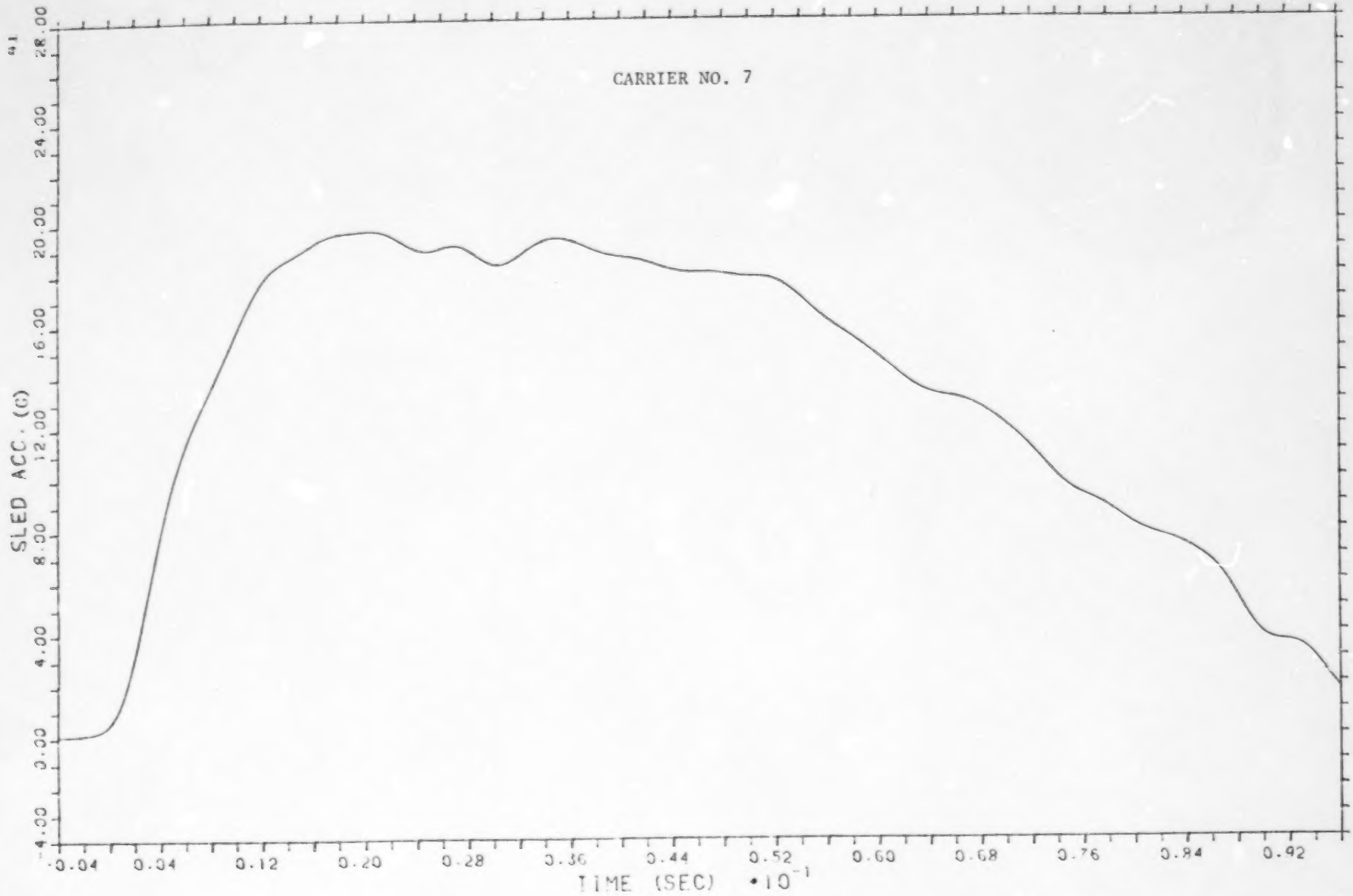
-4.00
-0.04
0.04
0.12
0.20
0.28
0.36
0.44
0.52
0.60
0.68
0.76
0.84
0.92
TIME (SEC) *10^-1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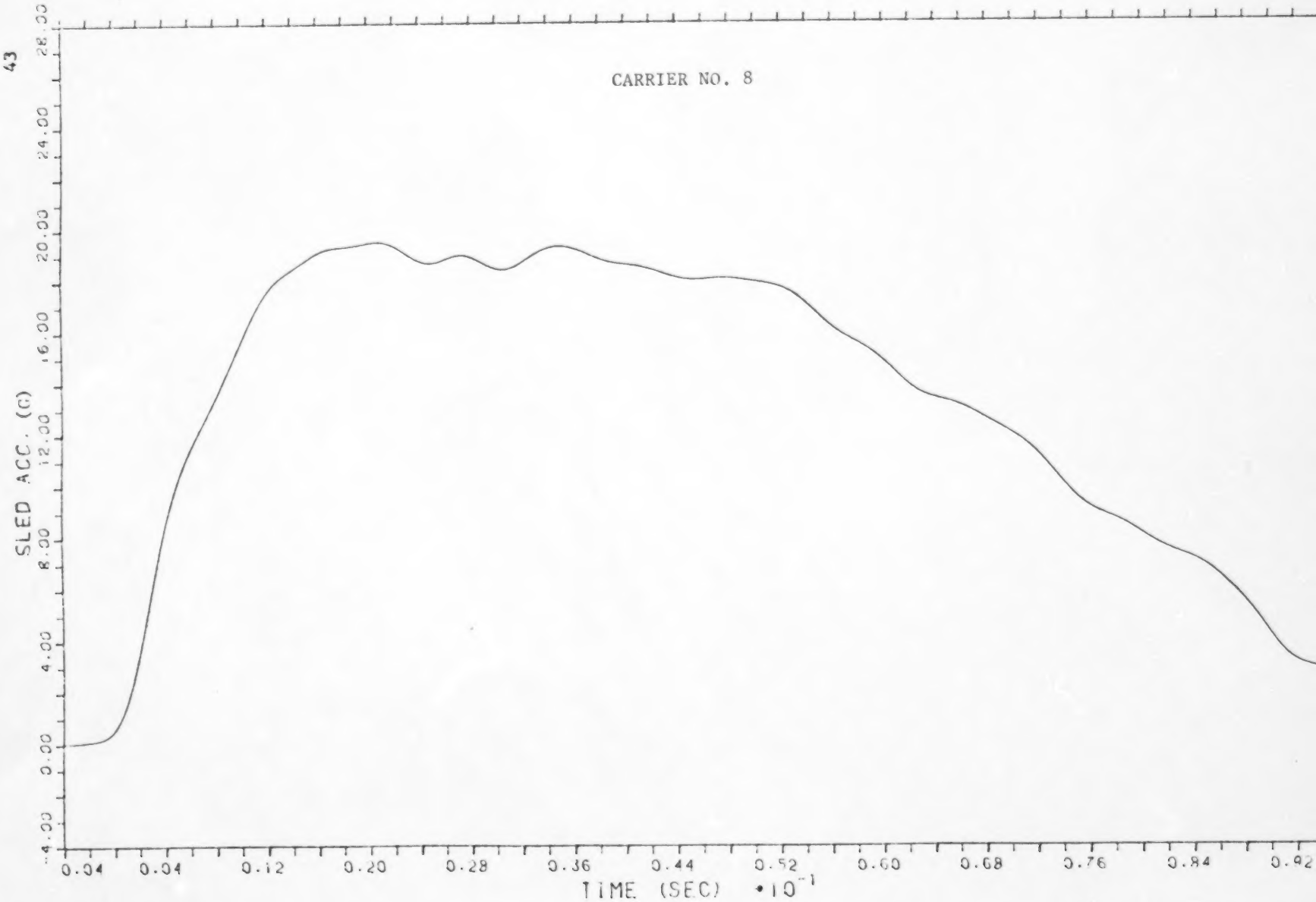
4.00
0.00
-4.00
-0.04
0.04
0.12
0.20
0.28
0.36
0.44
0.52
0.60
0.68
0.76
0.84
0.92
TIME (SEC) •10⁻¹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20.00
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28.00
0.04
0.04
0.12
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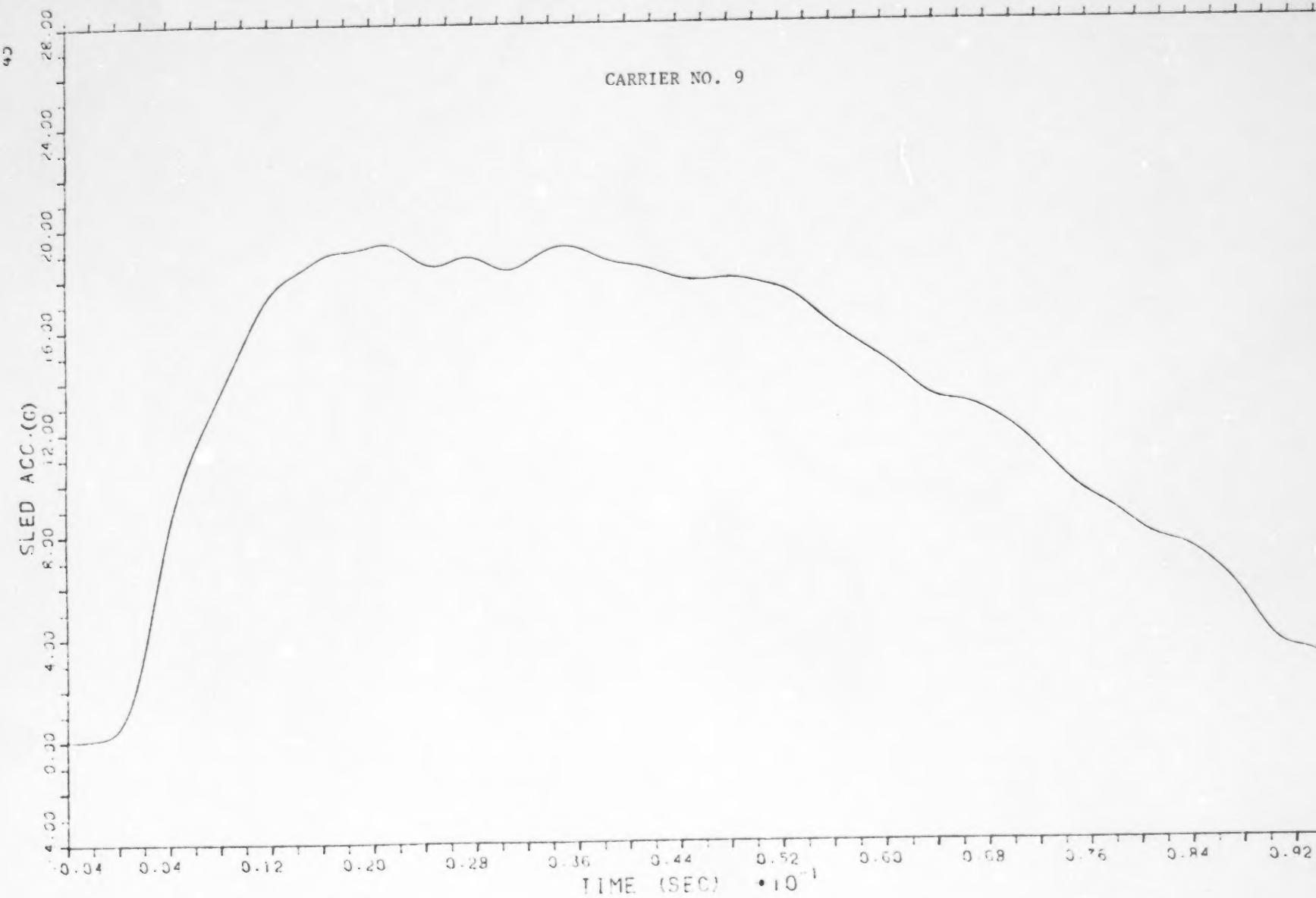
0.44
0.52
0.60
0.68
0.76
0.84
0.92
TIME (SEC) •10⁻¹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12.00
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4.00
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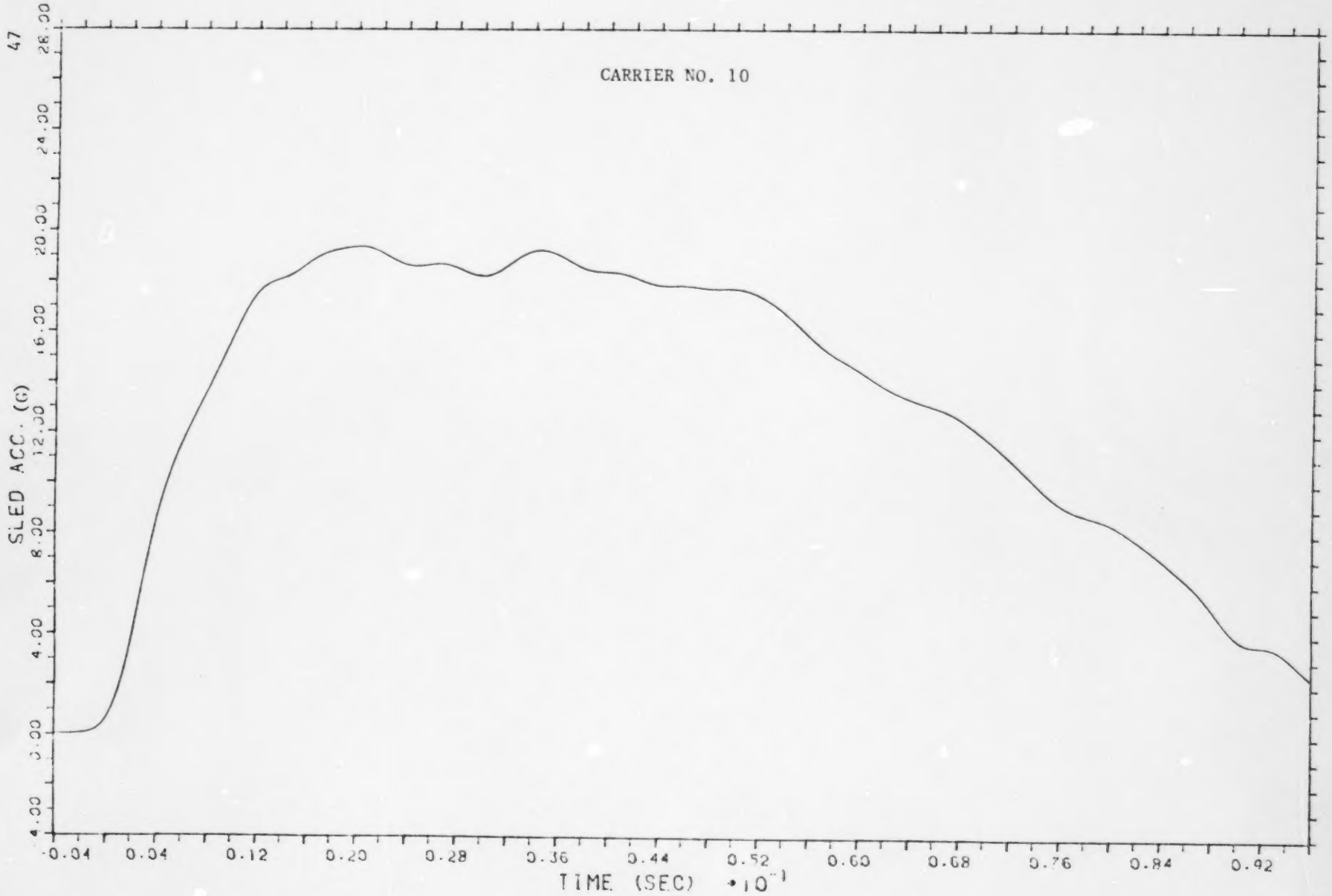
0.04
0.04
0.12
0.20
0.28
0.36
0.44
0.52
0.60
0.68
0.76
0.84
0.92
TIME (SEC) •10⁻¹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28.00
0.00
0.04
0.12
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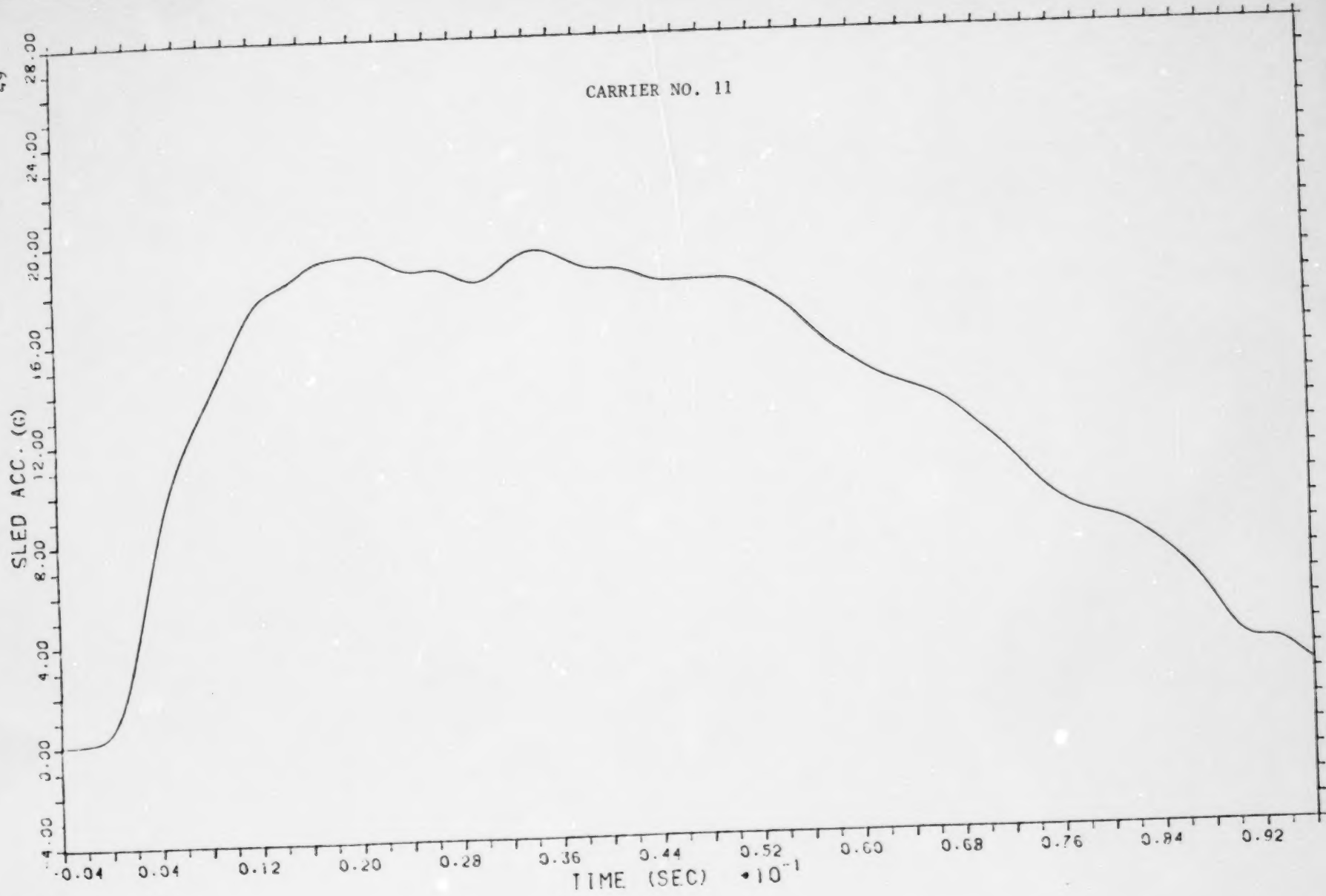
0.36
0.44
0.52
0.60
0.68
0.76
0.84
0.92
TIME (SEC) *10⁻¹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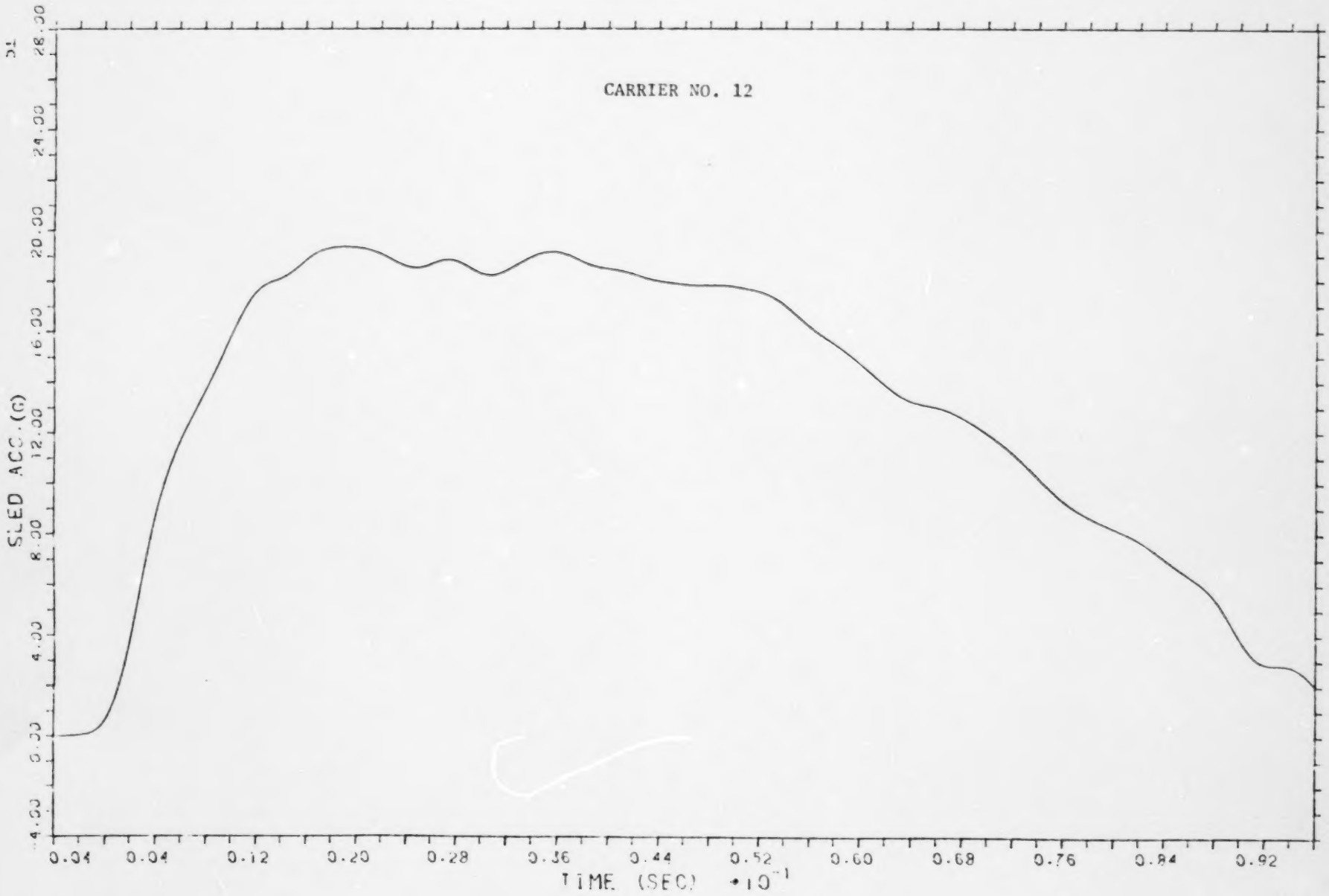
12.00
16.00
20.00
24.00
28.00
-0.04
0.04
0.12
0.20
0.28
0.36
0.44
0.52
0.60
0.68
0.76
0.84
0.92
TIME (SEC) *10^-1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TIME (SEC) *10⁻¹
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0.20
0.28
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0.44
0.52
0.60
0.68
0.76
0.84
0.92

Appendix D

Ammendments Proposed for
CMVSS 213.1 and MVSTM 213.1

CMVSS 213.1

1) sub-part 10(a):

This should be modified so that both the "radius" and "protrusion" criteria apply only within the interior contactable surface of the carrier.

2) sub-part 10(d):

Rather than stating the method for locating the back support surface here, reference should be made to the MVSTM (6), in which the determination of the back support angle should be more precisely laid out. (See also the amendment below proposed for sub-part 2.4.2(e) of MVSTM 213.1 below).

3) sub-part 12:

This sub-part should be changed to require testing of carriers only at the adjustment position(s) specified by the manufacturer.

MVSTM 213.1

1) sub-part 2.1.1:

Additions should be made to this section which specify that the foam slabs in the seat-back and seat-bottom

(i) be allowed to recover, outside of their vinyl covers, for at least 24 hours after each test; and

(ii) be used for only five and three tests, respectively, before being discarded.

2) sub-part 2.4.2:

Sections a, b, c, d, e, of this sub-part should be rearranged in the following order: a, c, b, d, e, in order to allow the seat lap-belt to be attached around the carrier after the infant restraint belt system has been tightened.

3) sub-part 2.4.2(c):

The test dummy should be positioned according to the instructions for infant positioning, rather than child positioning as stated.

4) sub-part 2.4.2(e):

A separate sub-part should be added here, using the method described in Appendix B, and giving the details of the procedure

for determining the specified point on the carrier back where the back support angle is to be measured, and the measurement of the angle itself.

5) sub-part 2.5:

As noted in section 4 of this report, there are numerous difficulties in performing this test. The main problem is that the attitude of the carrier, and the location of the buckles and automobile lap-belt both conspire to make buckle release force measurements very difficult, and in some cases, impossible. Also, the 20-pound buckle-loading force has no effect on buckle performance in most cases. It is felt that the results of this test have little practical value. DCIEM recommends that this test be replaced by a different, simpler test, in which the 20-pound pull force would be omitted, and a small tongue separation force applied, with neither the carrier body nor the dummy included in the test.

Alternatively, in the event that the existing test is retained, the following improvements are recommended:

- that sub-part 2.5.1(a) be changed so that the dummy is to be installed facing the front of the bench seat, rather than the rear. (Note, however, that some infant carriers cannot be made to face the front easily while being restrained by the lap-belt. This problem could be overcome, and a more uniform test conducted on all carriers, by securing the carrier to a workbench so that the carrier seat-bottom is horizontal).

- that a tongue separation force of one pound be specified

- that, for buckles with two tongues, the minimum allowable release force required for pullout of the first tongue be specified for pre-impact tests, and that the maximum allowable release force required for pullout of the second tongue be specified for post-impact tests.

- that reference to MVSTM 209 "Seat Belt Assemblies" in 2.5.1(e) be ommitted, and the relevant portions transferred to MVSTM 213.1.